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Distribution patterns of the Stone marten (*Martes foina* Erxleben, 1777) in Mediterranean mountains of central Spain

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Abstract

The distribution pattern of the stone marten (*Martes foina*) in a mountainous region of central Spain has been studied. The presence of the species was determined by searching for faeces along footpaths. Variables used in this study were selected in accordance with ecological requirements of the species and landscape descriptions from previous studies.

The distribution pattern was described by Principal Component Analysis (PCA), logistic, and multiple regression techniques. The results indicate that the stone marten is a mainly forest-dwelling species with preference for higher mountainous regions where human density is low. These data agree with previous studies carried out in the Iberian Peninsula and support the hypothesis of niche expansion in Mediterranean areas. They do not corroborate other authors' results, which suggest a preference of this species for urban habitats.

Key words: *Martes foina*, distribution, forest preference, Mediterranean areas

Introduction

Most studies on the ecology of the stone marten (*Martes foina*), especially those relating to diet and space use, have been conducted in central Europe (Libois and Waechter 1991 for a review, see also Clevenger 1994). Little is known, however, about the ecology and distribution patterns of this species in the Mediterranean region at the south of its distribution range (Libois and Waechter 1991). The studies in this area have focused on diet (Delibes 1978; Amores 1980; Ruiz-Olmo and Palazón 1993), and basic aspects of the spatio-temporal ecology of this species (Delibes 1983; Ruiz-Olmo et al. 1991; López-Martín et al. 1992; Genovesi et al. 1996).

In central European regions, the stone marten has been recorded as a species with synanthropic habits which prefers urban areas and villages to all other available habitats (Broekhuizen 1983; Kalpers 1984; Skirnisson 1986; Broekhuizen et al. 1989; Herrmann 1994). In Mediterranean areas, preliminary reports pointed out that this species is less dependent on villages and shifts its preference towards rocky or forest areas (Delibes 1983; Genovesi et al. 1996). These Mediterranean populations could give us important information on the behaviour and ecological characteristics of this species in areas distant from the region of sympatry with the pine marten (*Martes martes*).

The aim of this study was to describe the distribution of the stone marten in a Mediterranean mountain area in relation to forest types, human settlements, and other macrohabitat variables associated with stone marten preferences elsewhere.

Material and methods

Study area

The study area was located in forested habitats of the Guadarrama mountain range (Central Spain), covering a total area of 180,000 ha. This natural area is characterized by steep altitudinal gradients and by a varied human density. As a consequence of the pronounced relief, all the forest types characteristic of central Spain can be found within the area. The lowest level is covered by holm oak (*Quercus ilex*) forest and its serial succession scrub communities (*Cistus*, *Retama*, etc.). This ranges from 600 to 900 m and is the driest area with a dense human population. Between 900 and 1 200 m the Pyrenean oak (*Quercus pyrenaica*) forests are found, which are used as feeding pastures for cattle (dehesas). These forests are dominated by Pyrenean oaks and ashes (*Fraxinus angustifolia*). At the upper level there is a strip in which the oak forests have been replaced by pine trees (*Pinus sylvestris* and other pine species). Pine forests are found up to 1 700 m and have differing degrees of scrub coverage depending on the predominant type of land use. The climate at this altitude is colder and wetter and snow is common. A more detailed bioclimatic and botanic description can be found in Rivas-Martínez (1982).

Survey procedures

The field work was carried out in the winter season (November–March) between 1991 and 1994. The study was conducted over 18 plots (5×5 km each one) that corresponded with areas of homogeneous forest types and physiognomy: 5 plots corresponded to pine forest, 4 to Pyrenean oak forests, and 9 to holm oak forests. The number of plots corresponding to each forest type was proportional to the environmental availability of these forests in the area.

In each plot, sampling was carried out in four different subplots (0.62×0.62 km) in order to obtain an abundance index for each plot (measured as number of subplots with stone marten presence/number of subplots sampled). This type of index can be considered as a frequency of occurence (e. g. Gaston 1991), an appropiate measure of large-scale distribution studies in which just the species presence is of interest. Thus, this abundance index was used for subsequent analyses. In order to cover a wider area and maximize the likelihood of finding the species, two or three different transects (500–600 m long) were defined per subplot area (200 m evenly apart). Along these transects, stone marten faeces were searched for along foot paths and trails which are commonly used by this species (Waechter 1975).

It was considered that the species was present in a plot when at least one subplot had positive results. One subplot is considered as being used when the species was present in at least one of the transects.

Each subplot was visited once each winter and all transects were covered. No changes were detected in the frequency of occurrence of each plot between years (same number of subplots with the species' presence), therefore given values can be considered representative for the distribution pattern of the species in the area.

Variables measures

Each plot (5×5 km) was defined on land-use maps of the Spanish Ministry of Agriculture (1 : 50,000) and from a series of variables relating to stone marten preferences were measured for each: forest cover (percentage of the whole plot covered by forest); scrub cover (the same for many different types of scrub: *Cistus*, *Cytisus*, *Retama*); pasture cover; mean altitude (altitude calculated as the mean of ten random spots in the plot); roughness index (mean number of 50 m altitude curves counted from a three random west-east line-transects across the plot); human settlement cover (coverage of villages in the entire plot). The cover variables were measured using a 0.5×0.5 km grid superimposed on the land-use map and by counting the number of grids containing each variable type (forest, scrub, human settlement or pasture). The predominant forest type of the plot was also recorded (holm oak, pine or Pyrenean oak forest). The cover variables and roughness index were related to macrohabitat variables associated with preferences of the stone marten in central Europe and Mediterranean areas (e.g. Delibes 1983; Libois and Waechter 1991; Lachat 1993; Herrmann 1994).

Data analyses

We used a Principal Component Analysis (PCA) to describe the distribution pattern of the stone marten in the environmental gradient of these mountains. Also, a stepwise logistic regression (forward Wald Method, Norusis 1989) was performed to analyse the associations between PCA factors and presence/absence data in the 5×5 km plots (Norusis 1989). In addition, a more detailed stepwise multiple regression analysis (forward) was performed with the frequency of occurrence of stone martens as a response variable and the environmental variables as predictors (Neter et al. 1985). Forest types were categorized as 'dummy' variables (Neter et al. 1985) in this analysis.

All data were normalized prior to the analyses by square root (frequency of occurrence), decimal logarithm (altitude and roughness) and arcsin (cover of forest types) transformations (Zar 1984). Statistical analyses were performed with the SPSS package for Windows (6.0).

Results

Two factors were obtained from a Varimax rotated PCA with all transformed variables which explained 72.4% of the variance. The first was a gradient from high altitude, high forest and scrub cover, and high roughness index (positive scores), towards areas with a high human settlements cover (negative scores). The second factor segregates scrub (positive scores) and pasture areas (Tab. 1). The stone marten shows a clear distribution pattern where most of the positive plots correspond to positive scores of the first factor (areas of high altitude with low human settlements cover). However, the pattern is clearer when the frequency of occurrence is used. In this case the higher abundances (values of 0.5 or 1) were associated with positive scores of the first factor with only one "outlier" (Fig. 1).

Table 1. Results of the PCA performed with the variables used to study the distribution patterns of the stone marten.

Variable	Factor 1	Factor 2
Altitude	0.855	0.272
Forest	0.603	–0.415
Shrub	0.682	0.940
Pasture	–0.141	–0.772
Roughness	0.762	0.479
Human	–0.809	0.182
Eigenvalue	2.35	1.99
% Explained variance	39.24	33.14

Stepwise logistic regression with the two factors obtained from the PCA showed that only the first factor was significant ($G^2 = 7.4$, 1 df, $p < 0.01$) with 66.7% of the data correctly classified. Stone martens were primarily present in areas with high forest cover and altitude and low human density.

A simple regression between abundance and each individual variable was performed. Only altitude, human settlements cover, and roughness index were significant (Tab. 2). However, the three variables were highly intercorrelated, therefore, only the relationship with altitude was considered (see the correlation coeffcient in Tab. 2). Altitude is also highly correlated with forest type. However, the model obtained from a forward stepwise multiple regression with the forest types (as dummy variables) is more powerful than that obtained from altitude ($R^2 = 83.61\%$ vs $R^2 = 63.61\%$ of the explained variance for forest type and altitude, respectively). Stone martens were more abundant in high areas where the most important forest type is the pine forest (positive coefficient in the multiple regres-

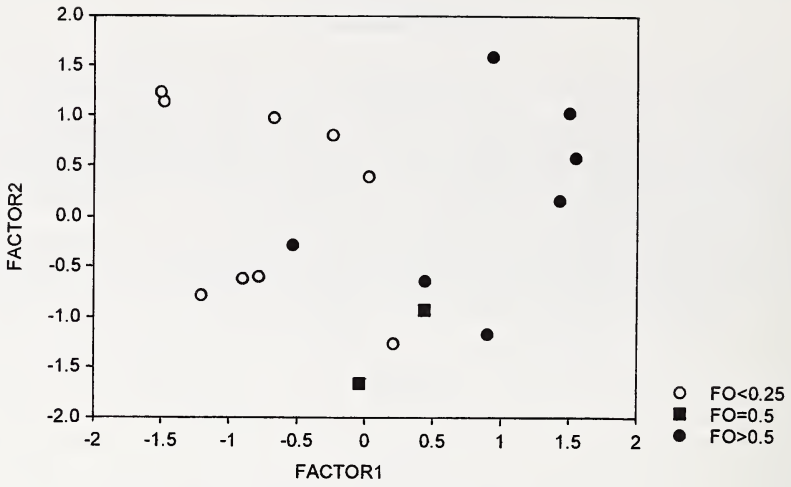

Fig. 1. Plot distribution on the environmental gradient generate from the PCA.

Table 2. Simple Pearson correlations (r) between the frequency of occurrence of the stone marten (FO) in each plot and the used variables.

Variable	Altitude	Forest	Shrub	Pasture	Rough	Human
FO	r = 0.81 p < 0.001	r = 0.34 p = 0.16	r = 0.01 p = 0.96	r = 0.01 p = 0.99	r = 0.66 p = 0.003	r = –0.51 p = 0.03

sion) than lower areas, mostly vegetated by holm-oak forest (negative coefficient in the multiple regression). Most probably, the strong relationship with forest type indicates the association of this species to pine forests, while this association is weak with Pyrenean oak forests (also at higher altitudes than holm-oak forests). Therefore, PCA and regression gave the same relationship between frequency of occurrence of this species and altitude (and their correlated variables: forest types, roughness, and density of human settlements).

Discussion

Our results support the suggestion that the stone marten is principally a forest dwelling species in the Mediterranean region, preferring to inhabit high areas where human settlements are scarce. This implies that, in spite of the fact that this species is not especially adapted to cold weather like the pine marten (Delibes 1983; Libois and Waechter 1991), the stone marten still prefers to inhabit cool areas between 1,200 and 1,400 m. Among the forested areas they showed a clear preference for pine forests (in the highest mountain areas), being rarer in Pyrenean oak and holm oak forests. Their reduced numbers in the lower holm oak woods could be explained by the increased hunting pressure in these areas (especially poisoning and other non-selective control techniques) although its scarcity in some areas with little hunting activity precludes any general explanation for this pattern. The lower abundance in Pyrenean oak forest could be due to habitat structures not studied here (e.g. the lower scrub cover of these habitats compared to others).

The coniferous forests mainly used by the stone marten in our area could correspond physically and structurally to the conifer forests over a large part of Europe (Ozenda

1982). Thus, according to our study its lower frequency of occurrence in these forests elsewhere does not seem to be attributable to the unsuitability of this habitat for this species. Our data do not, therefore, agree with the results obtained by Skirnisson (1986) and Herrmann (1994) which supposed suitability of the urban habitat for the stone marten. On the contrary, only one scat was found near human settlements and the species showed a clear preference for places far away from the more densely populated villages. This appears to be in accordance with the preliminary data of other Spanish researchers (Delibes 1983; Ruiz-Olmo et al. 1991). Therefore, the suggested advantages in the urban habitat (increased number of refuges and a wider range of available food) may vary in different areas. On the other hand, the effects of other variables that could potentially affect habitat preference, such as intraspecific and interspecific competition and predation risk (Mangel and Clark 1986; Rosenszweig 1991), both of which are probably important in the urban areas studied here (dogs and cats are very common), could be evaluated. These variable responses to habitat type have already been shown in the classical works of Heptner and Naumov (1974) who described the habitat differences between stone martens of the plains (synanthropic) and those of the mountains (forest or rock dwelling).

Could the habitat distribution of the stone marten in Mediterranean areas be explained by a niche shift of this species in a region of allopatry with the pine marten (Delibes 1983)? This explanation is possible although more detailed studies are necessary to test this hypothesis. However, there are other alternative possible explanation for this shift in preferences. The spatial configuration of habitats and their spatial and temporal availability could influence the distribution patterns and interactions among species (Danielson 1991; Hanski 1995 and references therein). In many of the areas studied in Europe there is a strong historical and present-day human disturbance and there is very low availability of forest habitats on a regional scale. Probably, in this scenario the stone marten would adapt to an environment that is increasingly less forested and could be selectively adventageous to shift its habitat preferences towards urban or rural environments (see Holt and Gaines 1992 for a theoretical approach). In contrast, in the Mediterranean mountains, forests are historically and currently more abundant and stone martens may select the available habitats according to their suitability. In this scenario, it is probable that the forests can be considered as the most suitable habitat for the stone marten. This hypothesis does not require the existence of competition between the two *Martes* species and future research is needed to investigate the underlying mechanisms that explain the observed pattern.

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Zusammenfassung

Verbreitungsmuster des Steinmarders (Martes foina Erxleben, 1777) in einer mediterranen Bergregion von Zentralspanien

Das Verbreitungsmuster des Steinmarders (*Martes foina*) wird in einer Bergregion Zentralspaniens untersucht. Die An- und Abwesenheit der Art wurde mit Hilfe von Kotfunden auf Fährten durch das Untersuchungsgebiet (5×5 km Plots) bestimmt. Die in dieser Studie benutzten Variablen wurden in

Übereinstimmung mit den ökologischen Ansprüchen der Art und den Faktoren des Makrohabitats der Landschaft ausgewählt.

Die Verteilungsmuster wurden mit Hilfe von PC-Analysen sowie logistischen und multiplen Regressionen beschrieben. Die Analysen zeigten, daß der Steinmarder eine hauptsächlich waldbewohnende Art ist, mit einer Vorliebe für höhere Bergregionen mit geringer menschlicher Besiedlung. Die Ergebnisse stimmen mit früheren Arbeiten überein, die auf der Iberischen Halbinsel durchgeführt worden sind, und sie unterstützen die Hypothese der Nischenexpansion in mediterranen Gebieten. Sie bekräftigen aber nicht die Ergebnisse von anderen Autoren, nach denen eine Präferenz dieser Art für urbane Gebiete vorliegt.

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